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LEADING ARTICLE

Duplex Ultrasound Investigation of the Veins of the Lower Limbs after Treatment for Varicose Veins — UIP Consensus Document CME

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Abstract *Objectives:* Duplex ultrasound has become the reference standard in assessing the morphology and haemodynamics of the lower limb veins. The project described in this article was an initiative of the Union Internationale de Phlébologie (UIP). The aim was to obtain a consensus of international experts on the methodology and terminology to be used for assessment after treatment of incompetent superficial and perforating veins in the lower limb by ultrasound imaging.
Design: The study design was consensus meetings leading to a consensus document.
Methods: The UIP invited group submitted relevant literature references and written contributions concerning the methodology, terminology and value of duplex imaging after treatment. The authors prepared a draft document that was circulated to a larger group of experts and revised according to the comments received. Eventually, all participants agreed upon the final version of the article.

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Results: Formal analysis of the results of interventions for varicose veins relies on adequate preoperative assessment and a careful description of the procedure employed. The timing of investigations of outcome should be classified as immediate (1—4 weeks), short-term (1 year), midterm (2—3 years) and long-term (5 years or more). The examination should employ standard methodology and formally described variables, which can be tailored to the intervention that was undertaken. The experts have made detailed recommendations concerning the methods to be used for duplex ultrasound examination and reporting after various treatments for varicose veins, including novel treatments under scientific study.
Conclusions: Duplex ultrasonography is a fundamental component of the investigation of the lower limb venous system after treatment for varicose veins.

Duplex ultrasound (DUS) is the most frequently used investigation to evaluate the outcome of treatments for chronic venous disease (CVD). Endovenous ablation (EVA) of a vein using laser or radiofrequency energy, or ultrasound-guided injection of sclerosant foam may all be evaluated using this technique. DUS imaging is the ideal non-invasive method for follow-up, as it provides anatomical and haemodynamic information about the treated veins.[1—9] DUS can detect the early stages of recurrent varicose veins, before they become apparent clinically.[10] Serial DUS imaging can not only help to understand the clinical evolution of the individual patient after treatment for CVD, but also has the potential to increase the general knowledge of events leading to clinical recurrence. Thus, long-term follow-up using DUS extends the understanding of the natural evolution of varicose vein disease.

Widely different DUS criteria have been used to assess the outcome of treatment for venous disease; often, there is very little information about the preoperative morphological and haemodynamic condition of veins. Currently, there is no systematic agreement from phlebology or vascular societies on how DUS imaging is best performed, or interpreted for follow-up. Standardisation of follow-up imaging and reporting would reduce the confusion and give better clarity to the end points of treatment.[11—13] The aim of this document is to summarise best practice for venous DUS examination of the legs after treatment, derived partly from the (limited) published evidence, and also agreed upon by an expert group that regularly uses this technology.

Methodology

The Union Internationale de Phlébologie (UIP) invited a group of international experts in the field of DUS investigation with MDM as the Chair. They were invited to submit relevant literature references and written contributions concerning the methodology and value of DUS imaging after treatment. Personal expert opinions were sought, which did not necessarily reflect policies of scientific or medical societies to which the individuals were affiliated. This process was not intended to form a systematic review of the literature, but to provide evidential support to the consensus recommendations made in the final document.

Consensus meetings began with interested experts at the Venous Forum of the Royal Society of Medicine in Manchester, November 2007, and subsequent meetings were held with smaller subgroups looking at specific areas. The aim was to define a systematic method of DUS imaging and reporting, which was simple to use and could be employed to audit the outcome of various treatments for varicose veins, including novel treatments under scientific study. The authors acknowledge that many of the statements only reflect the opinion of the consensus group rather than being supported by published scientific evidence. This reflects the fact that existing publications have used widely varying criteria for both methods and interpretation of DUS imaging after treatment.

Only the specifics of DUS imaging for the evaluation of treatment are considered. However, it is critical that these go together with the essentials of good clinical and patient-focussed evaluation. The tools for these have been published previously, such as Clinical, etiologic, anatomic and pathophysiologic data (CEAP), Venous Clinical Severity Score (VCSS) and other generic and condition-specific (e.g., the Aberdeen Varicose Vein Symptom Severity score, AVVSS) quality of life (QoL) assessments.[14—19] The relationship of these tools to specific DUS appearances is unfortunately not yet established. Further work is required, which should be stimulated by this consensus document. It is anticipated that, in future studies of global outcome following different treatment strategies, the present document should not be used in isolation, but should be used in conjunction with similar existing or newly produced consensus documents on clinical reporting.

While this consensus deals primarily with the DUS evaluation after treatment, it cannot ignore the state of the pre-treatment evaluation. Anatomical and haemodynamic characteristics of superficial venous insufficiency often vary widely between patients. Therefore, clear recording of pre-treatment clinical features and DUS findings is essential, as they may influence the interpretation of post-treatment results and expectations. The detailed documentation of the type of treatment employed is also important for the understanding of subsequent DUS findings. For instance, the length of the incompetent segment of the great saphenous vein (GSV) that was treated should be recorded, and the anterior accessory saphenous vein (AASV) should be distinguished clearly from the GSV. These pre-treatment details are unfortunately not always available, which may significantly reduce the value of DUS-based follow-up. The previous consensus document on recurrent veins after surgery (at that time called 'REVAS'), which integrated clinical and DUS findings, reported that, for the majority of patients, little information was

available regarding the type of procedure undertaken, or the date it was done.[20,21] In the recently published VeinTERM consensus document, the acronym PREVAIT (PREsence of Varices (residual or recurrent) After InTervention) has been introduced, referring to clinical scenarios where varices cannot definitely be classified as recurrent or residual.[22] In case of PREVAIT, interpretation of DUS findings is always difficult and potentially ambiguous. The present consensus document seeks to address this by insisting on the recording of all useful prior information, and on the requirement for prospective DUS evaluation for adequate interpretation.

DUS Imaging before Treatment

The basic principles of venous DUS investigation for varicose veins have been described in a previous UIP Consensus Document, and these remain applicable.[8] The ultrasound anatomy of the superficial and perforating veins has also been described in a UIP Consensus Document.[9] Since these publications, new treatments have emerged for which additional descriptive features are required, and these are included in the present document.

The minimum requirements for pre-treatment DUS assessment are described in Table 1. Other features may be recorded, but should not be at the expense of the minimum data set.

To assess the involvement of any pathology of the deep venous system, scanning the deep veins and looking for patency and the presence/absence of reflux is an important part of the evaluation of a patient before treatment of varicose veins. Some patients present with superficial vein disease due to underlying primary deep venous incompetence or secondary (post-thrombotic) obstruction and/or reflux. This will obviously influence the long-term outcome of treatment of superficial or perforating vein incompetence adversely and should therefore be included in the initial assessment as well as in further follow-up. In patients with a previous history of deep vein thrombosis, the deep venous system should be examined in both the lying and standing position to check for residual obstruction and reflux, respectively, as described previously.[8]

When assessing superficial veins, patients should be examined in the standing position where possible, to standardise measurements of venous diameter and reflux. If obesity or other cardio-respiratory conditions make this impractical, it is vital that any follow-up imaging is done in the same position.

Table 1 Preoperative duplex imaging.

1. *Deep veins*: assessment for patency and reflux
   - common femoral vein (CFV)
   - popliteal vein
2. *Junctions*: assessment for reflux (terminal valve/pre-terminal valve)
   - saphenofemoral junction (SFJ)
   - saphenopopliteal junction (SPJ)
3. *Main trunks*: diameter measurement and assessment of reflux (in the saphenous compartment):
   - great saphenous vein (GSV)
   - anterior accessory saphenous vein (AASV)
   - posterior accessory saphenous vein (PASV)
   - small saphenous vein (SSV)
   - thigh extension of SSV/Giacomini vein
4. *Tributaries*: if incompetent
5. *Non-saphenous veins*: if incompetent
6. *Perforating veins*: diameter measurement and assessment of reflux

Diameter measurement

This should be performed in transverse view and the outer diameter should be measured (including the vein wall) to compare this with the postoperative diameter after endovenous ablation. For the GSV trunk, diameter measurements of the incompetent segment should be made 3 cm below the saphenofemoral junction (SFJ), at mid-thigh level, at the knee and also at mid-calf level. The saphenous trunk should be measured at a site where there is no focal (or aneurysmal) dilation of the trunk.[23] Similarly, the AASV should be measured 3 cm below the SFJ and at mid-thigh (if the trunk exists at this level). For the small saphenous vein (SSV), the trunk should be measured 3 cm below the saphenopopliteal junction (SPJ) where the pre-terminal valve, if present, is located. A mid-calf measurement should also be made.

Assessment of reflux

The presence of flow in any part of the arterial or venous system assumes the existence of a pressure gradient; nor can venous reflux exist without a pressure gradient. In an individual standing still and breathing normally, flow in both competent and incompetent veins is very slow but remains antegrade. To detect the presence of reflux, it is necessary to create a pressure gradient in the venous system. This is usually achieved either by a Valsalva manoeuvre, which creates high pressure in the venous system, or by compression—release (calf squeeze), which creates a low pressure in the venous system during release.

There is a lack of standardisation in reflux assessment; the duration of reflux in seconds (reflux time) is used most commonly. Reflux is usually defined as retrograde flow lasting for more than 0.5 s, whereas less than 0.5 s is defined as normal or no reflux.[8] However, the reflux time can only be used to distinguish between a competent and incompetent vein segment and is therefore a qualitative evaluation. Peak reflux velocity (m s^{-1}) and the rate of reflux (ml min^{-1}) may be used to provide a quantitative evaluation of reflux.[24] Manual limb compression by calf squeeze cannot be standardised; hence, is not ideal for quantitative measurement of reflux. To obtain more reproducible results, two standardised methods for testing reflux have been evaluated in healthy subjects and patients with venous disease:

1. Standardised Valsalva manoeuvre: This consists of forced exhalation into a special tube system that measures expiratory pressure (Jeanneret—Valsalva device, Eisenhut® — VET Ag, Allschwil, Switzerland).

A pressure of 30 mm Hg should be established within 0.5 s and held for at least 3 s, to avoid false positive prolonged reflux due to a lack of transvalvular pressure gradient. This standardised Valsalva manoeuvre is highly reproducible in the proximal leg veins with coefficients of variation ranging from 10.4% to 13% for reflux time and from 11.5% to 16.4% for peak reflux velocity.[25] The Valsalva manoeuvre, however, cannot be used to assess reflux in veins distal to competent valves.

2. Standardised cuff inflation—deflation method: An automatic or manual pedal cuff inflator produces rapid inflation and deflation of cuffs placed at different levels on the leg.[26]

In most countries, these standardised methods are not used routinely. Most assessors use a Valsalva manoeuvre, together with calf compression—release to characterise venous incompetence. At the level of the SFJ, the combination of these two manoeuvres is essential to assess the state of the terminal valve (TV) of the GSV. The TV and the pre-terminal valve (PTV) of the GSV should both be identified, to distinguish between incompetence of both valves or only one of the two.[9] The assessment of TV and PTV haemodynamics is best achieved through the combined use of colour flow and Doppler modalities, with the sample volume placed above each valve to test for the presence or absence of reflux (at common femoral vein level to test the TV and at the most proximal part of the GSV to test the PTV).

In the groin, the lymph node area should be studied, particularly in patients with recurrent varicose veins. Reflux in a lymph node vein network (LNVN) should be sought, tracing it upwards looking for a connection with the common femoral vein or pelvic veins, and downwards looking for a connection with GSV, AASV or other varicose veins.[27]

In multiparous women, a leash of tortuous veins may also be seen within the saphenous compartment or superficial to the SFJ in the thigh. These veins mostly commonly connect with the abdominal—pelvic venous network and reflux may be elicited during Valsalva or calf release. They may or may not connect with the main trunk of the GSV or AASV. DUS imaging may reveal reflux in one or more of these visible veins.[28]

Details of Treatment or Procedure

Sufficient details of any treatment should be documented to permit informed DUS follow-up. These are described as minimum requirements in Table 2. Additional details can be included, as required, to fulfil the requirements of specific studies.

Table 2 Details of treatment.

1. Treatment of junction (SFJ, SPJ)
   - none
   - flush SFJ ligation
   - lower ligation with preservation of the junction itself
   - repeat ligation of SFJ or alternative procedure for recurrence
   - adjunctive procedures: closing opening in cribriform fascia, prosthetic patch on SFJ/SPJ
2. Treatment of main trunk (GSV, AASV, SSV)
   - none
   - endovenous laser ablation
   - radiofrequency ablation
   - (ultrasound-guided) foam/liquid sclerotherapy
   - stripping with vein stripper (invaginated or not) or cryostripping
   - length/site of treated trunk(s)
3. Treatment of tributaries
   - none
   - phlebectomies
   - foam/liquid sclerotherapy
   - endovenous laser treatment
   - delayed phlebectomies or sclerotherapy
4. Treatment of perforating veins
   - none
   - phlebectomy and epifascial ligation
   - foam/liquid sclerotherapy
   - radiofrequency ablation
   - endovenous laser ablation
   - subfascial ligation (SEPS)
   - site of treated perforating vein(s)

Timing of Post-treatment DUS Evaluation

There are several purposes for DUS follow-up. These include assessment of adequacy of the initial treatment and of complications, identifying possible need for further intervention, identifying the evolution of deterioration and recurrence, carrying out research into treatment mechanisms and outcomes and, in due course, to identify surrogate end points of long-term outcomes. The intended purpose, as well as the cost and the feasibility of inviting patients to re-attend, will influence the frequency of repeated assessments.

Immediate: 1—4 weeks after treatment

This is indicated:

(1) For single 'one—stop' treatments, such as surgery or endovenous thermal ablation, where it is desirable to know whether the intervention has achieved the intended immediate goal. Without this, it is impossible to determine whether recurrence, should it occur, is due to inadequate therapy (for instance, residual incompetent GSV trunk after stripping). The presence of post-treatment deep vein thrombosis should also be assessed.[29—33]

(2) As part of sequential treatments, such as staged (foam) sclerotherapy, combined procedures (phlebectomy + sclerotherapy), CHIVA (Cure Conservatrice et Hémodynamique de l'Insuffisance Veineuse en Ambulatoire) technique,[34] etc.

Late follow-up

For most patients, further DUS evaluation will be required for suspected recurrence. Repeat assessment is essential for

longer term prospective evaluation intended for the purposes of research or clinical audit. For these purposes, recommended follow-up is:

Short-term. Assessment should be performed 1 year after the intervention to elicit ultrasound features that may predict longer term outcome after treatment of GSV, AASV or SSV. A vein obliterated at 1 year after endovenous thermal ablation will usually remain so for at least 3–5 years in most cases.[35,36] After surgery, 1-year assessment detects newly developed incompetent veins (due to neovascularisation or dilation of pre-existing veins) in the treated areas.[37–41] The finding of new incompetent veins in the groin, which are larger than 4 mm in diameter, 1 year after SFJ ligation results in a 100% probability of developing a clinical groin recurrence and visible recurrent veins in the thigh after 5 years.[10]

Mid-term. This should be considered after 2–3 years to confirm the earlier changes; but, this interval after treatment is still too short for conclusions on long-term outcomes.[6,41–43]

Long-term. This should be performed at least 5 years after treatment.[6,36,44–47] This interval is long enough for the development of clinical recurrence, which may have arisen as a consequence of the incompetent veins detected by the short- or midterm DUS scan.[6,10,36]

In addition to DUS imaging, clinical findings should be evaluated using VCSS (or an alternative clinical score) and QoL assessment at the same time intervals.[12]

If possible, a late DUS assessment can be performed after 10 years or more.[46,48–50] The longest reported DUS follow-up after varicose vein surgery was done 34 years after treatment, but, for obvious reasons, this was not a prospective study.[51] In practice, it is not easy to achieve long-term follow-up in patients treated for varicose veins.

DUS Imaging after Surgical or Endovenous Treatment of Varicose Veins

Standardised preoperative DUS assessment and clinical evaluation (see above) should combine a written report with a diagrammatic representation of the data as an adequate basis for further DUS comparisons.[8]

A. DUS imaging after surgical treatment

Following surgical treatment, DUS imaging should focus on the saphenous junctions (SFJ and SPJ) and keep track of the stripped saphenous trunk (GSV, AASV or SSV). Sites of previous perforator ligation should also be investigated. Recurrent varices should be assessed as either:

(a) veins with reflux following a Valsalva or compression–release manoeuvre, where a change of compartment or escape point (connection with the deep veins) exists; and
(b) veins where the reflux is not linked to an escape point but is generated by the filling of the incompetent vein by its tributaries. In these veins, a Valsalva manoeuvre will not elicit reflux, whereas a compression–release manoeuvre will show reflux in the relaxation phase.

All 'escape points' should be documented, where possible; in many cases of recurrent veins, no clear communication with deep veins can be identified by DUS examination.[20,21,45]

DUS of the SFJ

The SFJ is a common site of recurrence following surgery.[21,52] After classic SFJ disconnection (flush saphenofemoral ligation and ligature-section of the related SFJ tributaries), also called crossectomy or high ligation, a number of features may be identified:

- *Normal*: This shows the common femoral vein (CFV) without any residual segment of GSV or any incompetent superficial vein in the groin, and the GSV terminal valve is no longer visible.
- *Neovascularisation or groin varicose network*: Neovascularisation is defined as new blood vessel formation (angiogenesis) occurring in abnormal tissue or in an abnormal position, which is a histological diagnosis. However, in the Vein-term consensus document, neovascularisation has been accepted as a venous term, defined as: "presence of multiple new, small tortuous veins in anatomic proximity to a previous venous intervention."[22] The consensus group has retained the term 'neovascularisation' to describe the presence of new veins situated at the site of the previous SFJ or SPJ ligation (Fig. 1(a) and (b)).[7,53–56] These veins may be newly formed or can arise from dilation of existing groin veins that were invisible on DUS before the operation. They can be observed in the short-term, mid-term or only at long-term follow-up.[46] The terms 'neoreflux', 'angiodysplasia' and 'cavernoma' should not be used anymore to avoid confusion with other conditions.[56–58] An alternative term for neovascularisation at the SFJ could be 'groin varicose network', which is a neutral descriptive term for the newly visible veins, without suggesting any underlying pathophysiology. If tortuous veins are seen in connection with a lymph node, they are properly described as LNVN and these findings may or may not be part of the neovascularisation pattern.[58] Neovascular veins are usually tortuous. They may exhibit reflux with a Valsalva manoeuvre, and/or during release after calf compression. Some neovascular veins have a normally directed flow without reflux. With time, these veins may establish a clear connection with superficial tributaries or with an LNVN, or with a retained saphenous trunk (which was not stripped intentionally or unintentionally) or with other veins present in the saphenous compartment after stripping, and become larger. The largest diameter of the vein(s) of the vascular network in the groin should be measured and the veins should be checked for presence or absence of reflux during calf compression–release and/or Valsalva manoeuvre. If these veins exhibit reflux with a Valsalva manoeuvre, the escape point usually lies in the SFJ area. In some cases, there is a connection with incompetent pelvic veins. If venous reflux is detected in neovascular veins only during the calf release phase (and not during Valsalva manoeuvre), this suggests that they fill from the subcutaneous abdominal venous

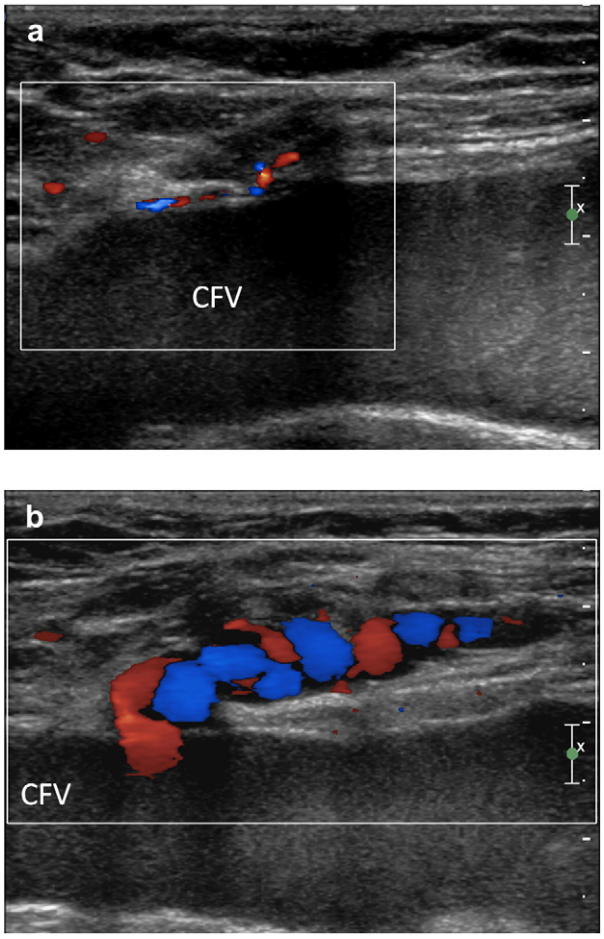

Figure 1 (a) Network of tiny refluxing veins originating from the common femoral vein (CFV) in the high ligation area suggesting angiogenesis (neovascularisation). (b) Network of large refluxing veins originating from the common femoral vein in the high ligation area without residual stump neither terminal valve.

network towards the groin, thigh and leg veins, without a direct communication (escape point) with the deep veins.

- *Residual stump*: If GSV ligation has been performed at a distance from the CFV (low ligation) instead of flush with the SFJ, a residual stump may be seen. The terminal valve can usually be seen with one or more residual SFJ tributaries. The most common pattern of recurrent veins is venous reflux via the SFJ, although this is commonly associated with reflux in residual tributaries. Reflux from the residual stump can connect with a residual AASV or other varices (Fig. 2). Where the terminal valve is competent, the stump receives inflow from its tributaries that drain normally into the SFJ. This pattern of flow is usually seen after successful EVA, but may also be found after selective stripping of the GSV trunk without a flush ligation, preserving the saphenofemoral confluence.[59,60] In prospective studies, the diameter of a residual stump should be measured and reflux in the stump or any of its connections should be assessed on DUS.

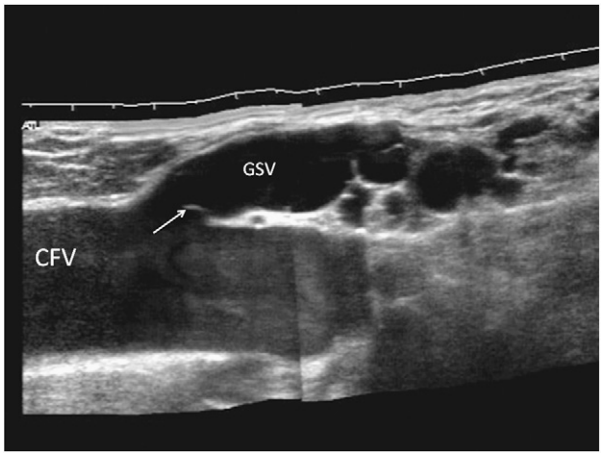

Figure 2 Network of large refluxing veins originating from the common femoral vein (CFV) through a residual GSV stump with the incompetent terminal valve still visible (arrow).

DUS of the above-knee GSV and of the AASV

After stripping of the above-knee GSV, the saphenous compartment should be examined, to see whether the GSV really is absent. If the GSV trunk is still completely or partially present within its 'saphenous eye', the diameter and length of the residual GSV segment should be recorded, and reflux assessed using a calf compression—release manoeuvre.

In the case of CHIVA, the persistence of the GSV trunk with retrograde flow is part of the treatment itself, which aims to redirect the saphenous blood flow towards competent re-entry perforators in the thigh or calf.[50]

In patients who have had surgical stripping, revascularisation of the strip-track has been observed, with the presence of multiple convoluted channels in the track of the previously stripped GSV.[61] It would be better to describe this only as 'multiple venous channels in the saphenous compartment' (see the primary varicose network described earlier).[28] The DUS image is typical in transverse as well as in longitudinal view (Fig. 3). Reflux can

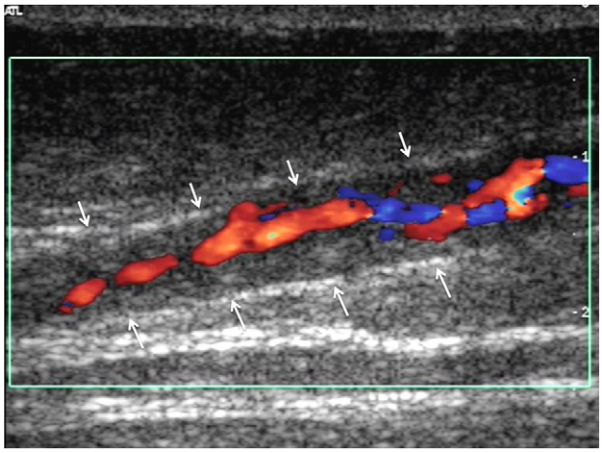

Figure 3 Early postoperative scan after GSV stripping showing haematoma still visible in the strip track (arrows) containing a network of multiple tiny refluxing veins.

be found in these venous channels and they may connect with clinically obvious recurrent varicose veins. Reflux may persist in the varicose network after stripping the GSV, or the varicose network may dilate and become incompetent postoperatively.

As the AASV is often involved in recurrence after GSV stripping, this vein should be examined along its course (usually from mid-thigh to the groin), including diameter measurement. In particular, connections with any possible escape point(s) usually located more cranially should be examined, for example, a residual stump, refluxing pelvic veins, LNVN, perforators, etc.

Much less common is recurrence in the posterior accessory saphenous vein (PASV) (sometimes in connection with a Giacomini vein). Typically in multiparous women, incompetent abdominal—pelvic veins can connect directly with residual GSV segments, or superficial tributaries in the thigh after surgery, although these may have been present before surgery.[28]

DUS of the below-knee GSV

The below-knee GSV is studied in its saphenous compartment. Residual reflux may be present in part or all of the saphenous trunk below the knee, and the diameter should be measured. GSV reflux within the saphenous compartment below the knee may re-enter the deep venous system through a distal re-entry perforator, without a connection to any superficial varicose veins.

DUS of the SPJ and SSV

After SSV surgery at the level of the SPJ, DUS findings are comparable to those at the SFJ after GSV surgery. However, it is important to have details about the preoperative anatomical and haemodynamic situation, as well as the procedure performed, as this will assist interpretation of the findings at the SPJ. Variations in SPJ anatomy are common and haemodynamics of the popliteal fossa are complex. The varying level of the SPJ in relation to the popliteal skin crease, the potential presence of a thigh extension of SSV or a Giacomini vein, the possible junction of the SSV with one of the gastrocnemius veins before joining the popliteal vein, the presence of a popliteal fossa perforating vein and all the different haemodynamic situations related to these anatomical variations has been described in detail in the two previous UIP Consensus Documents on DUS investigation (including an illustrative diagram).[8,9]

DUS imaging may highlight:

- *normal postoperative findings*. It is essential to specify, if ligation has been performed flush at the level of the popliteal vein, or at the confluence with one or more gastrocnemius veins; in the latter case, a residual stump has been left intentionally, since it represents a common track between gastrocnemius vein(s) and the proximal SSV.
- *neovascularisation, or popliteal fossa varicose network* with, or without reflux. Comparable to the situation in the groin, the neovascular veins may connect directly to the popliteal vein, or they may connect with incompetent veins in the posterior thigh (e.g., Giacomini vein, thigh extension of the SSV, pelvic or gluteal veins, sciatic nerve varices and sciatic veins). Typically, reflux is most obvious during calf release (diastolic phase). However, in a few cases, recurrent reflux within the varicose network in the popliteal fossa and/or in the residual stump may be elicited during calf compression or contraction (systolic phase), with, or without reflux during calf release. This specific haemodynamic pattern is exceptional and may indicate impaired outflow in the popliteal and/or femoral vein due to anatomical or functional abnormalities.[8]
- *residual stump*, with or without reflux. An incompetent residual stump is frequently seen after SSV surgery. This may arise from the great variation in level of the SPJ.[9] Unfortunately, data concerning the outcome of SSV surgery including mid- or long-term follow-up are extremely scarce and very few studies have focussed on the clinical recurrence rate and typical DUS appearances.[37,49,62—65]

Recurrent varicose veins after SSV surgery may be related to other kinds of anatomical and haemodynamic patterns:[9,66] (pre- or) postoperative incompetence of the popliteal fossa perforating vein, which is a tortuous vein, usually located laterally from the SPJ (Fig. 4(a) and (b)),

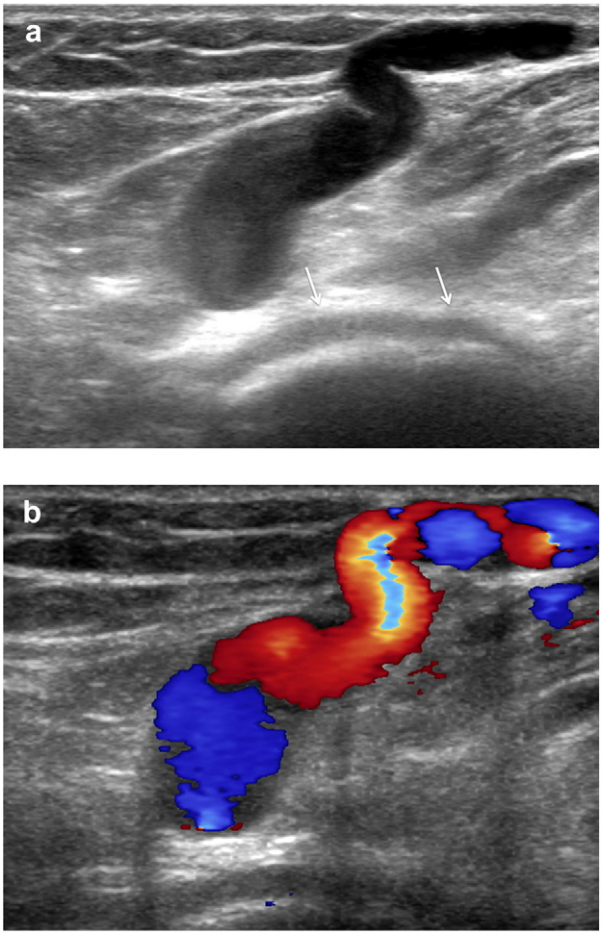

Figure 4 (a) A popliteal fossa perforating vein can be recognised from its typical location in front of the lateral condyle of the femur (arrows). (b) Colour duplex image shows reflux in this tortuous vein.

(pre- or) postoperative gastrocnemius vein incompetence or (pre- or) postoperative popliteal vein incompetence. Incompetent proximal veins (e.g., pelvic or gluteal veins, sciatic nerve varices (Fig. 5) and sciatic veins) can connect directly with residual SSV segments, and are frequently seen in women with pelvic varicocoele.

DUS imaging of perforating veins

Perforating veins are described according to their location above or below the knee, medial, anterior, lateral or posterior as described in the UIP consensus document.[9] Perforating vein incompetence is defined as a perforator that allows outward flow of >0.5 s during calf relaxation or release after distal compression.[8,22] The fate of perforating veins after surgical treatment has been studied extensively in a large prospective study, which included DUS assessment at 6 months, 1 year and 3 years.[67] This study showed that recurrent perforator incompetence after surgery is far more common than previously recognised; correct adjustment of DUS equipment is required to highlight low-velocity reflux during calf relaxation or release, which may occur in small perforators. In primary venous insufficiency, perforators that transmit part or the totality of the reflux from the superficial into the deep venous system are described as re-entry perforators.[8,68] After saphenous stripping and phlebectomy, they mainly show normal inward flow and a diameter reduction at short- and mid-term follow-up, though long-term data are still lacking.[69,70]

DUS imaging of tributaries and of non-saphenous veins

During DUS follow-up, the final report should include an assessment of the main incompetent tributaries, the intersaphenous veins and the non-saphenous veins (e.g., the lateral venous system).[9] On the back of the thigh, varicose veins may receive reflux from a gluteal plexus or vulvar/perineal veins, and are often related to pelvic vein incompetence. By carefully tracing these veins upwards while eliciting reflux with a distal compression—release manoeuvre, it is possible to detect the related pelvic vein reflux. If clinically indicated, in selected patients, this may be further evaluated by additional DUS or venographic investigation of pelvic veins.

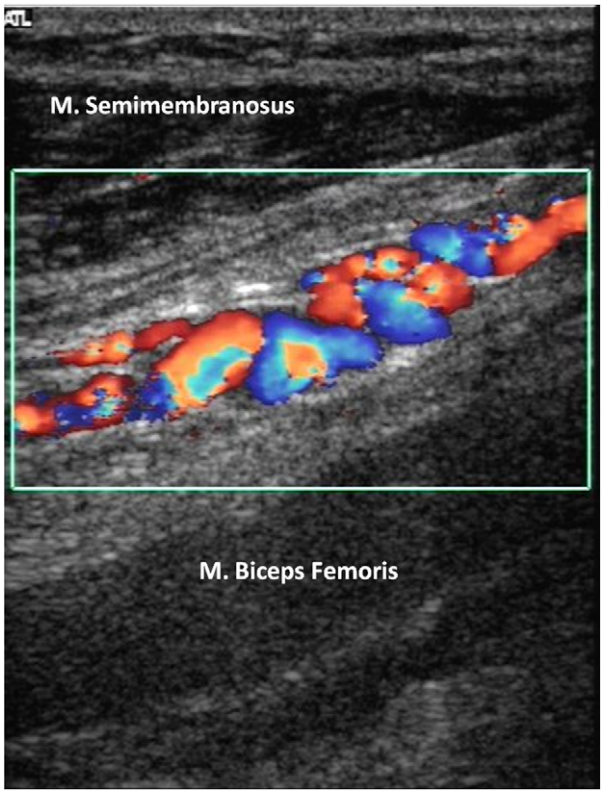

Figure 5 Sciatic nerve varices (posterior thigh view).

B. DUS Imaging after Physical or Chemical EVA (Laser, Radiofrequency or Foam Sclerotherapy)

EVA using laser energy, radiofrequency-generated thermal energy or a chemical sclerosant (most frequently as foam) has become increasingly popular for the treatment of varicose veins. Wide varying criteria have been used to classify the outcome after EVA.[71] A joint statement 'Recommended reporting standards for EVA for the treatment of venous insufficiency' has been published recently.[12] DUS efficacy criteria after foam sclerotherapy were discussed during a European Consensus Meeting in Tegernsee, Germany in 2006, and it was suggested these criteria could be suitable for other EVAs too.[13]

To evaluate EVA of the GSV, SSV or AASV, DUS investigation should focus on both the saphenous junctions (SFJ and SPJ) and on the treated trunk. If additional surgery of tributaries and/or of perforating veins has been performed, DUS findings will be reported as mentioned above. DUS imaging will describe the morphological and haemodynamic situation at the same follow-up intervals as those for evaluation of clinical outcome.

Thermal methods for EVA aim to obliterate the whole vein length between the site of introduction of the fibre or catheter and the incompetent junction. During radiofrequency ablation (RFA), the catheter tip is usually positioned 1 cm distally from the ostium of the superficial epigastric vein (2 cm from the SFJ).[72—74] For endovenous laser ablation (EVLA), the tip of the laser fibre is advanced to within 0.5 and 3 cm from the SFJ.[75—77] Similarly, for SSV treatment, the catheter or fibre tip is positioned 1—2 cm below the SPJ.[78—80] In ultrasound-guided foam sclerotherapy (UGFS) or catheter-directed foam sclerotherapy, an adequate volume of foam is delivered to obliterate the target vein, usually in one or two sessions.[13,43,81—83]

DUS of the SFJ

After endovenous treatment of the GSV with laser, RFA or foam, the terminal part of the GSV usually remains open and permits drainage of one or more tributaries of the SFJ.

- *Morphology: obliteration or patency?* The presence of a patent terminal portion of the GSV is considered to be a normal finding after endovenous treatment, if it is <3 cm in length. When only the distal incompetent part of the GSV has been treated, the competent proximal section will exceed 3 cm. The proximal section of the GSV may receive inflow from a Giacomini vein, pudendal veins and other tributaries.[72] At the immediate DUS scan (1—4 weeks after treatment), thrombus

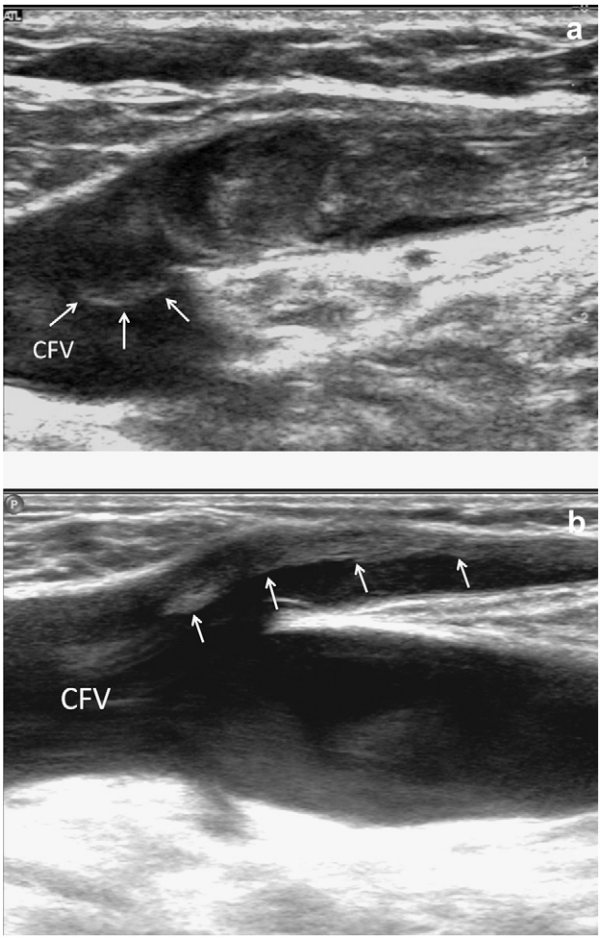

Figure 6 (a) Thrombus extension into the CFV *(arrows)* after thermal EVA (thrombus has developed in the GSV stump). (b) Thrombus extension into the CFV after foam sclerotherapy—thrombus has developed along the anterior wall of the GSV and CFV (arrows).

extension from the GSV into the CFV should be sought (Fig. 6(a) and (b)). Protrusion of a thrombus into the lumen of the CFV is very unusual (<1%) and should always be considered a pathological finding.[11,30–33,84,85] The extent of the thrombus should be assessed to assist in selecting appropriate treatment and monitoring.[86]

- *Haemodynamics: presence or absence of reflux.* Detection of low-velocity reflux requires proper adjustment of Doppler and colour modules,[8] and is of great importance in assessment after EVA, where vein compliance is usually reduced (because of diameter reduction or disappearance); tiny vessels may show reflux. To elicit venous reflux, a sufficiently high compliance is necessary, while the energy/pressure gradient is the second component.[87] After EVA, DUS usually shows a patent SFJ or SPJ with obliteration of the upper GSV/AASV or SSV. This obliteration dramatically reduces the compliance of the remaining few centimetres of patent vein. As a result, there is abolition of the energy gradient needed to generate reflux from the CFV through the SFJ, although valvular incompetence may still exist. Reflux will then not be detectable during Valsalva and compression—release manoeuvres in the proximal part of the GSV. The long-term haemodynamic fate of the residual saphenous stump after EVA is debated and its course should be monitored during DUS follow-up. Persistence or reappearance of reflux at the SFJ and/or at the level of the saphenous stump is always considered pathological. Any varicose veins in connection with this vessel should be imaged; infrequently, this consists of an incompetent non-obliterated saphenous trunk, but more often recurrent thigh varicosities connect with the incompetent part of the GSV in the groin, either through an incompetent AASV or PASV, or directly. In some cases, reflux can be provoked by a Valsalva manoeuvre or after thigh compression (more easily than after calf compression) in one or more tiny veins in the groin lymph node area and this finding mimics neovascularisation after saphenous stripping. Usually, no connection with any visible varicose veins is detectable at short-term follow-up. After EVA, the incidence of this DUS pattern is very low (0—1%).[88,89] The possible future clinical significance of this finding is not clear yet and the longest reported follow-up is limited to 5 years.[36]

DUS of the above-knee GSV and of the AASV

Obliteration of the trunk can usually be observed on completion of the procedure, but it usually takes 6—12 months before complete ultrasonographic disappearance is achieved.[72,89]

- *Morphology: obliteration or patency?* Treated veins (GSV and/or AASV) should be assessed by their compressibility, as well as using colour flow. It is standard practice to treat the whole above-knee GSV with EVLA and RFA and this vein should be obliterated in its entire course. Foam sclerotherapy may be less targeted, but, in most cases, a similar procedure and outcome is expected. However, the sonographic appearance of the obliterated vein will depend on the stage of post-treatment evolution. In the initial stages, the vein behaves differently depending on whether it has been treated with EVLA, RFA or foam.[90,91] Subsequent obliteration is characterised by progressive reduction in vein diameter, often in an inhomogeneous way over the length of the treated vein. In the final stage of fibrotic transformation, the vein may disappear completely on DUS imaging, or is transformed into a fibrous cord that may be visible as a hyperechogenic tract in the saphenous compartment. The time course of this whole evolution varies between patients.[89] The outer diameter of the obliterated vein can be measured, preferably on a transverse section, and the residual inner lumen of the visible vein can be assessed in case of partial or complete patency. Sometimes, an obliterated vein can be seen with an inhomogeneous content characterised by varying echogenicity, without flow or reflux, but with a lumen that can be partially compressed. The latter may be due to the presence of blood or thrombus in the lumen in an early stage.

- *Haemodynamics: presence or absence of reflux*. The presence of reflux following a Valsalva or compression—release manoeuvre is pathological. This reflux may be present over the whole length of the treated vein or may be segmental and the possible escape points should be described (SFJ, perforating vein, refluxing pelvic veins, etc.). Reflux distribution in the saphenous trunk and/or tributaries, together with the re-entry or refluxing perforators should be noted. Whether the reflux is due to primary failure of EVA treatment or re-canalisation after initial successful obliteration (usually within 6 months) can only be determined by performing serial DUS imaging. Antegrade flow without reflux can sometimes be demonstrated in a partially or completely patent residual GSV trunk. This may result from reduced vein size and the obliteration of re-entry points. No conclusive data are available to help interpret the significance of this finding, which might represent a good pathophysiological result, as the reflux is abolished.[13] The most important morphological and haemodynamic DUS findings after EVA of a saphenous trunk are summarised in Table 3.
- *Additional DUS evaluation above the knee*. As the AASV may be involved in recurrence after GSV ablation, this vein should always be examined along its course, and the presence or absence of reflux should be assessed.[76] Vice versa, after previous AASV ablation, the GSV main trunk should be examined at follow-up DUS. Although the PASV (and Giacomini vein) can also play a role in recurrence, this is far less frequent.

DUS of the below-knee GSV

Although it is still a controversial issue,[92] usually the GSV is ablated just to the level of the knee, even if the below-knee segment is also incompetent. Immediately after the EVA procedure, the GSV below the knee may remain competent or incompetent, or it may become incompetent again later at DUS after an interval. Partial or complete thrombosis of the below-knee GSV may occur after ablation of the above-knee GSV.

Table 3 Main morphological and haemodynamic duplex ultrasound findings after endovenous ablation of a saphenous trunk.

Morphology:
(a) obliteration of the vein: total incompressibility and absence of colour flow; the vein can be classified as visible or nonvisible
(b) partial patency of the vein: partial compressibility and presence of colour flow in a part of the lumen
(c) total patency of the vein: complete compressibility and presence of colour flow in the totality of the lumen
(d) outer diameter of the residual vein
(e) inner diameter of the residual lumen in case of partial or total patency
(f) segmental obliteration/patency: length of the obliterated, partially or completely patent segment(s)
Haemodynamics:
(a) absence of flow with both principal manoeuvres (Valsalva, compression/release)
(b) antegrade flow during compression manoeuvre
(c) retrograde flow >0.5 s during one or both manoeuvres

DUS of the SPJ and SSV

Sonographic changes after endovenous treatment of the SSV have been described less frequently than after GSV treatment. Changes in the SPJ and SSV seem to be similar to those of the SFJ and GSV, and should therefore be reported in the same way. At the SPJ, proximal tributaries may remain patent, particularly any extension of the SSV into the thigh or the Giacomini vein. Taking into account the variable level of termination of the SSV, the length of patent SSV considered acceptable after treatment should take the level of the SPJ as reference, rather than the skin crease of the popliteal fossa. After EVA of the SSV, obliteration of the treated SSV segment should be assessed and the residual distal SSV segment should be tested for reflux.

DUS imaging of perforating veins

Incompetent perforating veins can be treated with laser or radiofrequency using a technique-limiting thermal ablation to a short vein segment, or with foam sclerotherapy. The efficacy of all these treatments can be evaluated with DUS imaging, illustrating the obliteration of the treated perforating vein and abolition of outward flow during the release (diastolic) phase of the compression—release manoeuvre.[8,93,94] Perforating veins that remain patent should be reassessed to compare the normal inward flow and pathological outward flow, with the aim of determining the net flow. The latter is obtained by comparing mutually pulsed Doppler curves of inward and outward flow during distal compression and release.[8,68] The course of the reflux should be traced whenever it extends from the perforating vein into any saphenous or tributary vein.

Standardisation of results after EVA in view of scientific studies

The authors propose a classification (Table 4) allowing precise analysis of the results after EVA, to enable comparison of different techniques and to introduce

Table 4 Proposed classification of duplex findings at the junction (J) and at the treated trunk (T) after endovenous ablation.

J: for SFJ or SPJ:
- J0: no patent stump
- J1, J2, J3, J4 etc.: junction with patent stump of 1, 2, 3, 4 cm etc.
R+: reflux; **R-**: no reflux
T: for GSV/AASV/SSV trunk:
- Ti: invisible trunk
- To: obliterated trunk (diameter: .... mm)
- Tp: completely or partially patent trunk (diameter: .... mm)
- To/Tp or Tp/To: segmental obliteration/patency or patency/obliteration (length of patent segment: ... cm; diameter of residual lumen: ... mm)
R+: reflux; **R-**: no reflux

a standard DUS assessment of outcome following any EVA procedure. The situation at the level of the junction (J) and the treated trunk (T) is recorded. Reflux is reported as present (R+) or absent (R−). DUS findings at the level of the SFJ or SPJ are described as J0, J1, J2, J3, J4, etc., according to the absence of any visible stump (J0) or the presence of a stump with a patent length of, respectively, 1, 2, 3, 4 cm etc. If reflux is present, the site of connecting refluxing tributaries should be specified. DUS findings at the level of the treated saphenous trunk are reported as Ti (invisible), To (obliterated) or Tp (patent) or a combination of the latter in case of segmental obliteration. The presence or absence of reflux is reported as R+ or R−. If reflux is detected, the site of refluxing tributaries should be described. Measurement of diameter and length of the obliterated and/or patent segment of the saphenous trunk are described using the same protocol. When the lumen of the treated vein is partially obliterated in a segment of the treated vein or in its total treated length, the diameter of the residual lumen can be measured as well (Table 4).

The Role of DUS Investigation in Clinical Studies

Clinical outcome studies are designed to measure the impact of therapy on clinically relevant variables, such as patient satisfaction, quality of life and relief of symptoms. They also examine clinical signs, such as the presence of varicose veins, oedema and skin changes including venous ulceration. DUS ultrasound assessment is used to complement the clinical evaluation, assessing the technical success of treatment, which may determine the long-term evolution of the treated leg. DUS is also ideal for quality control of the initial intervention. Ideally, it is performed by an independent observer. DUS data are objective and reproducible, particularly when obtained and reported using standard methodology, which facilitates reliable collection of serial data in individual patients and in patient groups.

Using a single grading system for clinical outcome that combines symptom scores, clinical findings and DUS findings to define the global outcome will result in an incoherent system, as the relative importance of individual variables may differ. It is therefore appropriate to report separately on clinical outcome parameters and DUS findings in all patients included in prospective studies, focussing on the outcome of treatment of varicose veins, and the effect on other grades of chronic venous disease.

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Appendix
Supplementary data

Supplementary data related to this article can be found online at doi:10.1016/j.ejvs.2011.03.013.

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